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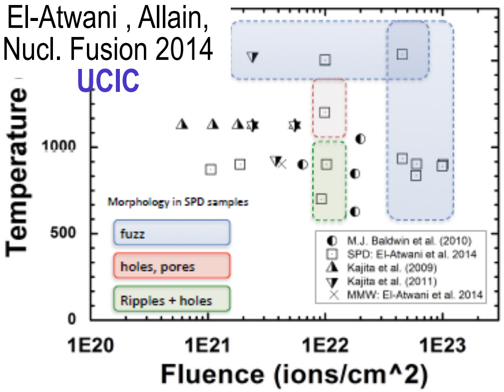
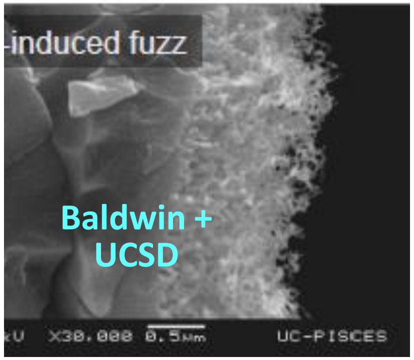
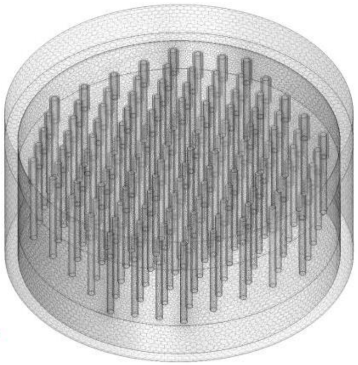
New after ReNeW: growing understanding of materials issues with tungsten, greater computational capability (materials, CFD), advanced manufacturing methods

El-Atwani , Allain, Nucl. Fusion 2014
UCIC







Related White Papers

- **Garrison***, ORNL
- **Parish***, ORNL
- **Unterberg***, ORNL/GA
- **Wright***, MIT
- **Singh****, ARL
- **Whyte, Tillack, ...**

** young researchers, **SBIR*

Advance Manufacturing and Engineered Materials
- A new vision for materials and PFC development -

Nygren[1], Youchison[1], Wirth[2], Snead[3]
[1]Sandia, [2]U. Tennessee, [3]formerly ORNL

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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PFM W solution
overcome limitations of bulk tungsten

For Plasma Facing Materials (PFMs) for FNSF, *inherent limitations for bulk W and C are evident by 30 dpa*. (earlier*)

*White Paper, Chad Parish, ORNL

- 10% of W has transmuted to Osmium that embrittles W,
- graphites begin to swell and loose mechanical integrity,
- **k_{rad}/k** (thermal conductivity) for W and C is ~50% and ~40%.

direction forward

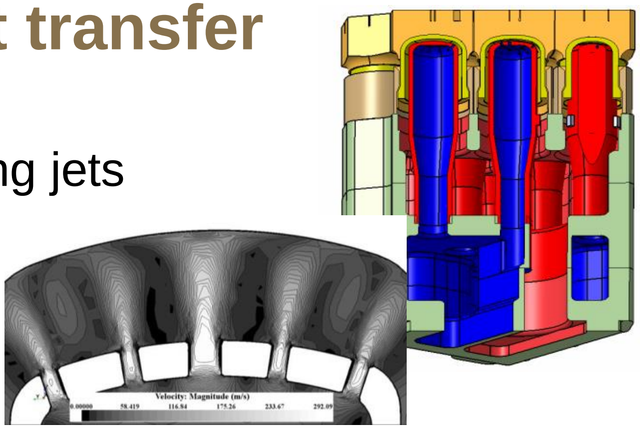
Experiments, modeling and opinions of experts (W Workshops) move us toward a view of desired features (below) in a W-based PFM that

1) enable migration of He and transmutation products to benign sites,
2) mitigate tritium permeation, and
3) maintain adequate robustness for a satisfactory lifetime.

Advanced manufacturing methods offer the potential to design and build suitable materials architectures for a satisfactory PFM.

PFC gas cooling solution
change scale for optimal heat transfer

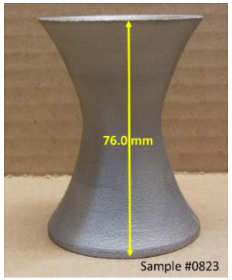
We can achieve high efficiency heat transfer and minimize thermal stresses with arrays of impinging jets when the feature size is small enough to defeat excessive turbulence at boundaries where the flow of adjacent jets meet.

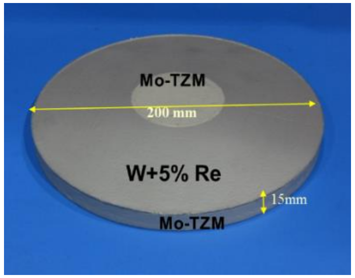


direction forward

Arrays of low pressure air micro-jets typically 100-500 µm dia. that cool steel or copper are prevalent in electronics. Heat sinks for high power devices like Insulated Gate Bipolar Transistors and Si-Controlled Rectifiers as well as solid state switching devices like MOSFETS, JFETS and RF power transistors are examples.[10] Arrays with many hundreds of jets are fabricated using MEMS technology such as lithography combined with advanced additive manufacturing technology such as LENS, LIGA or SPS.[11-15]
from Youchison, TOFE 2014 paper draft

The complex coolant passages for a gas-cooled DIII-D tiles can be made with field assisted sintering. White paper by Jogender Singh, Applied Research Lab, Penn State U. shows 8" disc and 3" tall thin-walled nozzle.





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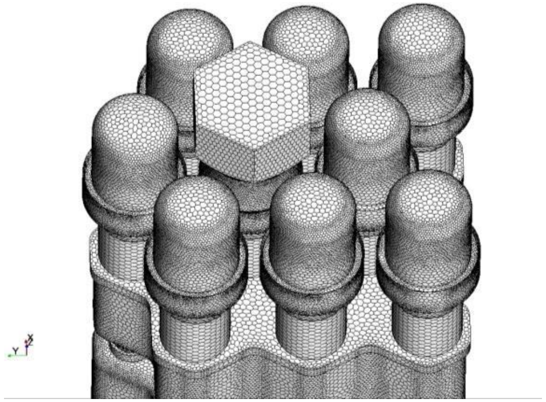
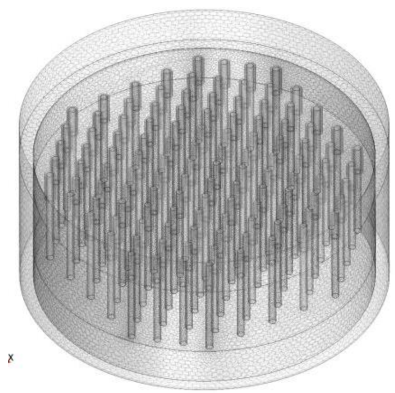
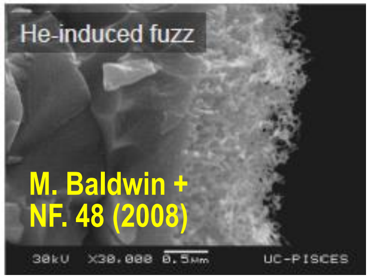
Additive manufacturing is an essential element in the combined solution for a robust PFM-PFC solution.





To realize robust PFCs for FNSF, we need

- suitable **materials architecture** for PFMs,
- **engineered micro-features** (microjets for gas cooling),
- **advanced manufacturing methods**, and a
- new vision of the R&D path for materials and PFCs.



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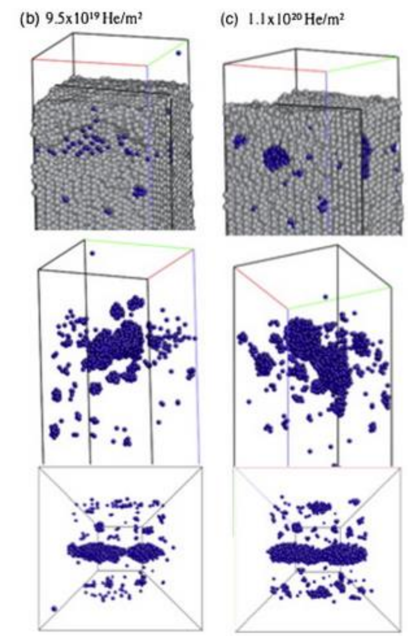

B. Wirth et al., and opportunities of modeling plasma–surface interactions in tungsten using high-performance computing, JNM in press

PFM-PFC Performance

Comments on PFM-PFC and additive manufacturing

While a concern for long term neutron damage still exists for the PFM, the solution for robustness of the PFM can be somewhat different than that for the substructure. For example, the basic requirement for the strength of the material may be drastically reduced. Nor is the radiation damage now a feature of a "bulk material" in a thick armor.

+ We can separate the ion-damaged PFM (weak, ?porous) and engineered substructure (strong, vacuum boundary) in nearer term R&D.

  This has significant implications for models & tests, e.g., surrogate materials.

- Developing predictive models of performance and converging on workable PFCs at a reasonable cost will be challenging due to the number of variables (porosity, nano-features, composition gradients, appropriate data on radiation effects, processing temps, ...)

Close collaboration between modelers and experimenters is a must. This means not just that modelers use experimental data, but that modeling is a tool both for identifying needs for data and for designing experiments, e.g., what can and should be measured.

Recommendation for Action

The vision outlined here is not yet accepted.

And certainly our development program is not aligned with this approach. Let us pick two important objectives and related near-term tasks.

One important objective for PFMs is the capability for predictive modeling of performance and generation of data to benchmark the models.

An important corollary in this new approach is the utility of surrogate materials in both modeling and testing that will advance the modeling even if these are not appropriate for end use in a PFC. To this end we can identify some useful tasks.

- Use experts in materials and PSI and identify PFMs for DEMO or FNSF.
- Use materials experts and identify fab methods for FNSF and for DEMO.
- Identify materials (surrogates as needed) to validate models and for use testing in off-line facilities as well as exposures in DIII-D, NSTX-U and perhaps foreign devices.